Planetary Suit Hip Bearing Model for Predicting Design vs. Performance

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Intro: Designing a planetary suit is very complex and often requires difficult trade-offs between performance, cost, mass, and system complexity. In order to verifying that new suit designs meet requirements, full prototypes must eventually be built and tested with human subjects.

Using computer models early in the design phase of new hardware development can be advantageous, allowing virtual prototyping to take place. Having easily modifiable models of the suit hard sections may reduce the time it takes to make changes to the hardware designs and then to understand their impact on suit and human performance. A virtual design environment gives designers the ability to think outside the box and exhaust design possibilities before building and testing physical prototypes with human subjects. Reductions in prototyping and testing may eventually reduce development costs. This study is an attempt to develop computer models of the hard components of the suit with known physical characteristics, supplemented with human subject performance data.

Objectives: The primary objective was to develop an articulating solid model of the Mark III hip bearings to be used for evaluating suit design performance of the hip joint.

Methods: Solid models of a planetary prototype (Mark III) suit's hip bearings and brief section were reverse-engineered from the prototype. The performance of the models was then compared by evaluating the mobility performance differences between the nominal hardware configuration and hardware modifications. This was accomplished by gathering data from specific suited tasks. Subjects performed maximum flexion and abduction tasks while in a nominal suit bearing configuration and in three off-nominal configurations. Performance data for the hip were recorded using state-of-the-art motion capture technology.

Results: The results demonstrate that solid models of planetary suit hard segments for use as a performance design tool is feasible. From a general trend perspective, the suited performance trends were comparable between the model and the suited subjects. With the three off-nominal bearing configurations compared to the nominal bearing configurations, human subjects showed decreases in hip flexion of 64%, 6%, and 13% and in hip abduction of 59%, 2%, and 20%. Likewise the solid model showed decreases in hip flexion of 58%, 1%, and 25% and in hip abduction of 56%, 0%, and 30%, under the same condition changes from the nominal configuration. Differences seen between the model predictions and the human subject performance data could be attributed to the model lacking dynamic elements and performing kinematic analysis only, the level of fit of the subjects with the suit, the levels of the subject's suit experience.

Complex motions are always best represented with visual 3D graphics. A virtual model of this type is also capable of quantifying and visually representing in 3D the dissimilarities between needed human motions to perform tasks and the motion allowed by the Mark III hip bearings while performing tasks. Visually quantifying these differences will give designers a faster and deeper comprehension of suit component performance and may help to optimize suit designs to match the needed human performance.